

UNITED STATES UTILITY PATENT APPLICATION

FOR

PROCESSOR TEMPERATURE CONTROL INTERFACE

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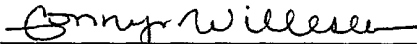
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# PROCESSOR TEMPERATURE CONTROL INTERFACE

## BACKGROUND

### 1. Field

[0001] The present disclosure pertains to the field of electronic components. More particularly, the present disclosure pertains to a temperature control interface for an electronic component such as a processor.

### 2. Description of Related Art

[0002] Controlling the temperature of electronic components is an ongoing struggle as components continue to shrink, yet often consume more power. Microprocessors now employ sophisticated techniques to allow power conservation and to throttle themselves when temperatures reach certain thermal metrics.

[0003] For example, one prior art processor includes a stop clock pin that allows the system to stop the processor clock for various reasons. One known use of this pin is to provide a periodic waveform on the stop clock pin, causing the processor to periodically stop and re-start processor (see, e.g., US Patent 5,560,001). Such clock throttling effectively reduces the processor operating rate, thereby typically reducing power consumption and temperature.

[0004] Additionally, the prior art processor may itself have thermal sensors and may perform its own internally-initiated throttling. When internally-initiated throttling for thermal reasons is employed, an external signal may be asserted to alert the system (see,

e.g., PROCHOT# output signal of the Pentium® 4 Processor).

[0005] These mechanisms, however, may not provide adequate control and/or synchronization capabilities for some applications.

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## Brief Description of the Figures

- [0006] The present invention is illustrated by way of example and not limitation in the Figures of the accompanying drawings.
- [0007] Figure 1 illustrates one embodiment of a system having a bidirectional processor hot interface.
- [0008] Figure 2 is a flow diagram illustrating operations of the system shown in Figure 1 according to one embodiment.
- [0009] Figure 3 illustrates one embodiment of a multi-processor system utilizing a processor hot interface.
- [0010] Figure 4 is a flow diagram illustrating operations of the system shown in Figure 3 according to one embodiment.

## Detailed Description

[0011] The following description describes techniques for a processor temperature control interface. In the following description, numerous specific details such as logic implementations, clocks, signal names, types and interrelationships of system components, and logic partitioning/integration choices are set forth in order to provide a more thorough understanding of the present invention. It will be appreciated, however, by one skilled in the art that the invention may be practiced without such specific details. In other instances, control structures, and gate level circuits have not been shown in detail in order not to obscure the invention.

[0012] In one embodiment, a bidirectional processor hot (PROCHOT#) interface is provided to allow both system observation and system control of a processor's thermal state. Such a bidirectional interface may be useful, for example, in desktop and mobile systems where a limited amount of control and observation capabilities are to be balanced with the use of additional pins. In another embodiment, a two pin PROCHOT# and force processor hot (FORCEPH#) interface allows the system to both observe and control assertion of a throttling mechanism.

[0013] A "processor" may be formed as a single integrated circuit in some embodiments. In other embodiments, multiple integrated circuits may together form a processor, and in yet other embodiments, hardware and software routines (e.g., binary translation routines) may together form the processor. Many different types of integrated circuits and other electronic components could benefit from the use of such temperature control techniques.

For example, the processor 100 may be a general purpose processor (e.g., a microprocessor) or may be a special purpose processor or device. For example, digital signal processors, graphics processors, network processors, or any type of special purpose component that may be used in a system may benefit from system visible and controllable throttling.

[0014] Figure 1 illustrates one embodiment of a processor 100 having a bidirectional processor hot interface (PROCHOT# interface node 117). The interface may be a pin, ball, or any other type of connector or set thereof that can provide at least one interface node to interface to other components. The processor 100 includes temperature monitoring logic 110 which monitors the temperature of the processor itself. A variety of known or otherwise available temperature monitoring techniques may be used. For example, a built in circuit that monitors temperature may be used. Alternatively, external sensors may be used or power consumption estimation techniques (e.g., activity counters/monitors, current monitors, etc). The temperature monitor 110 is coupled to an output driver 115 which drives the interface node 117 via a signal line 112 for a TOO HOT signal. The TOO HOT signal is also routed to throttling logic 120 through a multiplexer 130. The multiplexer is controlled by a fuse 140, which selects between unidirectional and bidirectional modes of operation in the illustrated embodiment.

[0015] In the embodiment of Figure 1, system logic 150 interfaces with the processor 100 and may drive via a driver 155 or receive via an input buffer 160 the PROCHOT# signal. The system logic may itself include some thermal sensors to determine when the overall system has reached an unacceptable temperature level, and may accordingly drive the PROCHOT# signal.

**[0016]** Operations for one embodiment of the system of Figure 1 are shown in Figure 2.

In block 200, the different modes of operation are separated out. In some embodiments, semiconductor fuses may be blown to select the mode of operations. Other selection techniques such as configuration registers and the like may also be used to select the mode of operation. In an output only mode, the fuse 140 causes the multiplexer 130 to select TOO HOT as the input to the throttling logic 120. Thus, the external state of the PROCHOT# signal is not considered, making PROCHOT# effectively output only as indicated in block 205.

**[0017]** In a bidirectional, single pin mode, both the system logic 150 and the processor 100 can drive PROCHOT# to control throttling. As indicated in blocks 215 and 225 the processor 100 monitors its temperature and monitors the PROCHOT# interface. If the temperature does not exceed a selected metric, then the processor continues monitoring the temperature, as indicated in block 220. Similarly, if the PROCHOT# signal is not asserted, the processor 100 will continue to monitor the interface as indicated in block 230. If either the PROCHOT# signal is asserted or the temperature exceeds the selected metric, then processor operations are throttled by throttling logic 120 as indicated in block 240.

**[0018]** The throttling performed by the throttling logic may be any appropriate known or otherwise available throttling technique. For example, the clock to the device may be periodically stopped. Alternatively, the processing throughput may be reduced by limiting throughput at some stage of the pipeline. Alternatively, the clock frequency may be changed. These or any other techniques that effectively reduce the amount of processing by the processor may be used by the throttling logic.

[0019] In a third mode, a bidirectional, dual pin PROCHOT# implementation may be used, as indicated in block 210. Figures 3 and 4 provide further details of one embodiment using a dual pin implementation. A dual pin implementation may allow both observation of the processor's internal gauge of temperature and assertion of a throttling command. With a single pin, asserting the throttle command would mask the processor's assertion of the same pin. In the embodiment of Figure 3, two processors are shown for illustrative purposes, but additional processors could be added. The processor 300 and the processor 350 both have FORCEPH# and PROCHOT# pins. Signal lines 364 and 362 respectively couple the FORCEPH# signals driven by the system logic to processors 300 and 350, and signal lines 302 and 352 respectively carry the PROCHOT# signals driven by the processors 300 and 350 to the system logic.

[0020] The processor 300 includes a monitor 310 to detect when the processor 300 is too hot (or in some embodiments when too much power is being consumed). Each numbered block represents a delay element such as a latch. A driver 305 is coupled to receive a TOO HOT signal from the monitor 310 and to drive a PROCHOT# signal on a signal line 302. A first path to a multiplexer 330 takes the TOO HOT signal through delay block 313-1 and delay block 313-2 and to a "w" input of the multiplexer 330. A second path to the multiplexer 330 takes the TOO HOT signal through the delay block 313-1, past the output driver 305 (also therefore picking up any externally asserted signals on signal line 302), through an inverting driver 307, and through delay blocks 314-2 and 314-3 to a "b" input of the multiplexer 330.

[0021] A third path to the multiplexer includes inputs from both signal line 302 (PROCHOT#) and from a signal line 364, which is driven by system logic 360. The



signal line 364 may be a force processor hot (FORCEPH#) signal line which allows external considerations to be used to determine when to throttle operations. In one embodiment, a system may wish to begin throttling of multiple processors simultaneously (i.e., during the same clock cycle of the external bus clock), even if both processors would not have simultaneously throttled themselves. In this embodiment, it may be desirable to match delays of the TOO HOT signal to the throttling logic 320 to the delay expected through the path of the system logic. For example, in the embodiment of Figure 3, the TOO HOT signal passes through delay block 313-1, the output driver 305, through delay block 316-2, combinational logic 363, delay block 316-3, into system logic 370, through delay block 316-4, combinational logic 371, delay block 316-5, back to system logic 360, through delay block 316-6, combinational logic 367, delay block 316-7, and then into a second processor 350. Assuming the second processor to have identical logic to that shown for processor 300, the path continues through elements corresponding to an input buffer 309, two more delay blocks 316-8 and 316-9, an OR gate 311, and an "F" input of the multiplexer 330.

[0022] Similarly, the path of the TOO HOT signal internal to the processor 300 includes 9 delay blocks and the OR gate 311. Internally, in the dual pin mode, the TOO HOT signal passes through delay blocks 313-1 and 313-2, and then through delay blocks 315-3 through 315-9, and into OR gate 311. The OR gate provides the multiplexer 330 with an indication that throttling should be performed if either the system logic 360 and 370 assert FORCEPH# on signal line 364 or if the monitor 310 indicates that throttling should be performed. The system logic components 360 and 370 may be local (360) and global (370) control application specific integrated circuits (ASICs). Whether any or all of the

logic is separate or integral is not, however, crucial to the disclosed techniques. Logic may be included in the processors themselves, in other system components such as bus bridges, or in ASICs or the like. Additionally, the absolute number or length of the various delays is not crucial; however, providing delay matching is desirable for some embodiments.

[0023] In the embodiment of Figure 3, the two control inputs to the multiplexer (fuseBiDirProcHotEn and fuseMPdecode) control which mode is selected. If the fuseMPdecode fuse indicates that the multiprocessor (dual pin) PROCHOT#/FORCEPH# implementation is desired, then path "f" to the multiplexer is selected. If the fuse fuseBiDirProcHotEn indicates that the bidirectional mode only is desired, then the input "b" of the multiplexer is selected. If the fuses indicate that neither the bidirectional nor the multiprocessor (dual pin) mode is desired, then the output-only mode is used, and path "w" to the multiplexer is selected.

[0024] Figure 4 illustrates operations for a multiprocessor system in which the dual pin mode is selected (e.g., path "f" on the multiplexer 330 of the embodiment of Figure 3). In block 400, a high temperature is sensed (e.g., by monitor 310). In block 410, the PROCHOT# signal is asserted to the system logic. As indicated in block 420, the internal TOO HOT signal is delayed. In the embodiment of Figure 3, the path through delays 313-1, 313-2, and 315-3 through 315-9 provides delays. As indicated in block 425, the asserted PROCHOT# signal also propagates through the system logic, incurring delays, and results in generation of the FORCEPH# signal to other processor(s) in the system. For example, in the embodiment of Figure 3, the FORCEPH# signal may be asserted to the processor 350 on the signal line 362.

[0025] Due to the delay within the first processor, which is designed to match the delay in the path through the system logic in addition to any internal delays, the processors begin throttling in synchronization as shown in blocks 430 and 435. It may be desirable in some systems to have such synchronization of throttling to keep processors operating at a uniform rate, thereby roughly equalizing progress and thermal/power concerns. Accordingly, a processor may be forced into a throttling state even where that processor would not have otherwise entered the throttling state.

[0026] Thus, techniques for a processor temperature control interface are disclosed. While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art upon studying this disclosure.